Forever Yuck: Oculomotor Avoidance of Disgusting Stimuli Resists Habituation

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Draft version 2, 6/30/20. This paper has not been peer reviewed. Please do not copy or cite without author's permission.

Abstract

Disgust is an adaptation forged under the selective pressure of pathogens. Yet disgust may cause problems in contemporary societies due to its propensity for "false positives" and resistance to corrective information. Here, we investigate whether disgust, as revealed by oculomotor avoidance, might be reduced through the non-cognitive process of habituation. In each of three experiments, we repeatedly exposed participants to the same pair of images, one disgusting and one neutral, and recorded gaze. Experiment 1 (*N*=104) found no decline in oculomotor avoidance of the disgusting image after 24 prolonged exposures. Experiment 2 (*N*=99) replicated this effect and demonstrated its uniqueness to disgust. In Experiment 3 (*N*=93), we provided a gaze-contingent reward to ensure perceptual contact with the disgusting image. Participants looked almost exclusively at the disgusting image for 5 minutes, but resumed baseline levels of oculomotor avoidance once the reward ceased. These findings underscore the challenge of reducing disgust.

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Disgust is a basic emotion elicited by offensive stimuli (e.g. spoiled food, bodily waste) associated with disease transmission (Oaten et al., 2009). By preventing contact with disease vectors, disgust may provide an adaptive response to the selective pressure of pathogens (Tybur et al., 2013). Although the ultimate function of disgust seems clear, its proximate functioning can be puzzling. As Rozin and colleagues (1986) revealed in their seminal study on the laws of sympathetic magic, disgust responding is often excessive and irrational. Evolutionary psychologists explain such findings through the “smoke detector principle”: In the same manner that smoke detectors favor false positives over false negatives, disgust may have been calibrated by natural selection to err on the side of caution (Schaller & Park, 2011).

Despite the calculus behind the smoke detector principle, too much disgust can be costly. Excessive disgust interferes with life functioning in several mental disorders (Olatunji et al., 2017). Disgust may also contribute to prejudice and discrimination towards marginalized groups, often through hateful rhetoric that associates group members with pathogen threats (Inbar et al., 2009; Nussbaum, 2003). Disgust may even have environmental costs, because it undermines sustainable practices, such as eating insect-based protein (Tan et al., 2015) and drinking recycled wastewater (Rozin et al., 2015). Thus, identifying strategies for reducing disgust could have applied value at both the individual and societal level.

Unfortunately, disgust may not respond to leading methods for reducing negative emotions. Cognitive restructuring, a method of reappraising situations that elicit negative emotions, may have limited efficacy with disgust (Mason & Richardson, 2012). Royzman and Sabini (2001) suggest that reappraisal of a disgusting stimulus is futile, because disgust is elicited by concrete, sensory properties rather than propositional thoughts about the world. Similarly, Russell and Giner-Sorolla (2013) suggest that disgust is elicited by simple associative links rather than situational appraisals that can be modified by reasoning or contextual information. In addition, several studies have shown that conditioned disgust resists extinction learning, perhaps because disgust is acquired through evaluative conditioning, which is less contingent on beliefs about the CS-US relationship (Engelhard et al., 2014).

In light of the potential "cognitive impenetrability" of disgust (Royzman & Sabini, 2001), it may be fruitful to target the emotion through simpler learning mechanisms. The most primitive form of learning is habituation, a non-cognitive process by which repeated exposure to a stimulus attenuates responding (Thompson, 2009). Habituation has primarily been studied in sensory-motor reflexes; however, it can be observed in emotional responding as well (Bradley et al. , 2003). Indeed, Emotion Processing Theory (Foa & Kozak, 1986; Foa, Cuppert, & Cahill, 2006) posits that within-session fear habituation is a necessary element of successful exposure therapy, as reduced fear in the presence of threat provides contradictory input to the "fear structure." Although subsequent research has questioned the importance of within-session habituation for treatment outcome (Baker et al., 2010), habituation may still play an important role, for example, by allowing a sense of mastery over one's emotions (Fentz et al., 2013).

Habituation may explain success overcoming normative disgust in non-clinical settings. In a naturalistic study, Rozin (2008) found that a cadaver rotation reduced medical students' disgust sensitivity to death and body envelope violations, but not other disgust domains. Although habituation may explain these findings, it is possible that other factors (e.g., goal pursuit) played a role. Disgust habituation may also underlie the "source effect," in which participants report less disgust to malodors from familiar (oneself or one's partner) versus unfamiliar sources (a stranger; Stevenson & Repacholi, 2005). However, the source effect may be explained by judgment biases favoring the self rather than habituation (Miller, 1997; c.f. Stevenson & Repacholi, 2005). Laboratory studies attempting to isolate the process of habituation have shown mixed results, with some observing similar rates of habituation for disgust and fear (Cougle et al., 2007) yet others finding slower habituation of disgust compared to fear (Rouel et al., 2018).

One limitation of the disgust habituation literature is that it relies mostly on self-report measures. Reported declines in disgust in some studies could be due to perception of demand characteristics or mislabeling of reductions of other negative affective states (Royzman et al., 2017). To provide further insight into disgust habituation, the present study leverages eye tracking for a novel, objective indicator of disgust. Prior research suggests that "oculomotor avoidance" (the tendency to look away) correlates with self-reported disgust (Armstrong et al., 2014) and may be specific to disgust (Bradley et al., 2015).

Here, we describe three experiments. In the first, we examined whether oculomotor avoidance of a disgusting image persists across numerous repeated exposures to the same image. If disgust is resistant to habituation, one would expect sustained avoidance of disgusting stimuli. In the second experiment, we examined whether oculomotor avoidance is specific to disgust, and if disgust is less prone to habituation than fear. If oculomotor avoidance is specific to disgust, one would expect only disgusting stimuli to be viewed less than accompanying neutral stimuli. If fear is more prone to habituation, one would expect more rapid decay of oculomotor responding to fear across exposures. In the third and final experiment, we examined whether failure to observe disgust habituation was due to oculomotor avoidance undermining exposure. To encourage perceptual contact during exposure, we provided a financial reward for viewing the disgusting image. If disgust is indeed resistant to habituation, oculomotor avoidance of a disgusting image should return after participants maintain gaze on the disgusting image for several minutes.

Experiment 1

In this experiment, participants underwent repeated exposure to a disgusting image paired with a neutral image. To examine generalization, we included a second block with a novel image pair. To test habituation, we examined change in dwell time on the disgusting image compared to the neutral image over the sequence of exposures. A decrease in relative dwell time on the disgusting image, as indicated by a slope across trials, would provide evidence of habituation. We also assessed psychometric properties of oculomotor avoidance by examining correlations with self-reported disgust and disgust sensitivity (convergent validity), and test-retest reliability between blocks.

Methods

Participants. An unselected sample of students (N=104, age in years M=19.8, SD=1.35, min=17, max=23; 33% men, 67% women; 74% White, 3% Black, 5% Hispanic or Latino/a, 6% Asian (including 1% Indian), 1% native Hawaiian, and 11% multiracial) at a private college in the Northwestern USA completed the experiment for extra credit in a psychology course or a $10 gift card.

Power. In each experiment, we sought to recruit approximately 100 participants, because this sample could be collected in one semester at a small liberal arts college. For one-sample and related-samples t-tests, the minimally detectable effect size was d=0.15 at 80% power and α=0.05. This reflects the smallest unit of analysis here, reflecting parameter estimates in linear mixed effects models, and trial-level comparisons.

In addition to null-hypothesis significance testing, we employed equivalence testing in the form of two one-sided tests (TOST), specifically one-sample t-tests. At 80% power and α=0.05, a sample size of 100 affords equivalence bounds (in Cohen's d) of -0.3 and 0.3 (Lakens, 2017).

Measures.

The *Disgust Scale—Revised* (DS-R; Olatunji et al., 2007) is a 25-item questionnaire assessing sensitivity to a range of disgust elicitors, including core (e.g., "You are about to drink a glass of milk when you smell that it is spoiled"), animal-reminder (e.g., "You see a man with his intestines exposed after an accident"), and contamination disgust ("You take a sip of soda, and then realize that you drank from the glass that an acquaintance of yours had been drinking from"). The resulting total score reflects one's general proneness to disgust (i.e., trait disgust). Half of the items are statements describing one's disgust response to various stimuli, with responses ranging from 0 = "Strongly disagree" to 4 = "Strongly agree"; the other half of items ask participants to rate different disgusting scenarios, with responses ranging from 0 = "Not disgusting at all" to 4 = "Extremely disgusting." The DS-R had good internal consistency ($\alpha = .84$) in the present sample, and has been shown to have adequate split-half reliability and convergent validity with other measures of individual differences in disgust (Olatunji et al., 2007). In a behavioral validation study, responses to the Disgust Scale (on which the DS-R is based) were moderately correlated with behavioral avoidance as measured across 26 disgust-inducing tasks (Rozin et al., 1999).

The *Empirical Valence Scale* (EVS; Lishner et al. , 2008)) is a labeled magnitude scale designed for rating subjective experiences. In contrast to the equidistant verbal labels of visual analogue or Likert-like scales, the verbal labels on the EVS are spaced according to prior research assessing how participants rate the verbal labels themselves on a 0-100 scale. Participants rated how pleasant-unpleasant and aroused-unaroused the images made them feel using the bipolar EVS scale, and how disgusted and afraid the images made them feel using the unipolar version of the EVS scale. The unipolar version of the scale contains the following labels and corresponding values: not at all (0), barely (13), slightly (25), mildly (38), moderately (50), strongly (81), extremely (87.5), and most imaginable (100). The bipolar version of the scale contains the following labels and corresponding absolute values: not at all (0), barely (7), slightly (14), mildly (29), moderately (36), strongly (71), extremely (86), and most imaginable (100). These labels are placed on a line (without the corresponding numeric values). Ratings are made by clicking anywhere on the line with a mouse.

Materials. An independent sample (*n* = 20) rated a set of disgusting images drawn from publicly available online resources, as well as the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008)) and neutral images drawn from the IAPS in terms of how disgusting the images made them feel and how complex they were, in light of possible effects of stimulus complexity on dwell time (Bradley et al., 2011). Two images of feces were selected that were similar in disgust ratings. Images of feces were selected because it is considered the most reliable disgust elicitor (Rozin & Fallon, 1987), and because using two images of the same type of disgusting object would increase the likelihood of observing generalization, given the discrimination in disgust habituation observed by (Rozin, 2008). Two neutral images of household objects (a scarf and buttons) were selected that best matched the complexity of the disgusting images they were paired with. Images were resized to 400 x 300 pixels (6.0 x 4.5 degrees of visual angle) and were presented over a black background with centers located 640 pixels (9.5 degrees of visual angle) apart horizontally. We computed the low-level visual saliency (Itti et al., 1998) of the display with both images, and found that they were well matched (Figure 1).

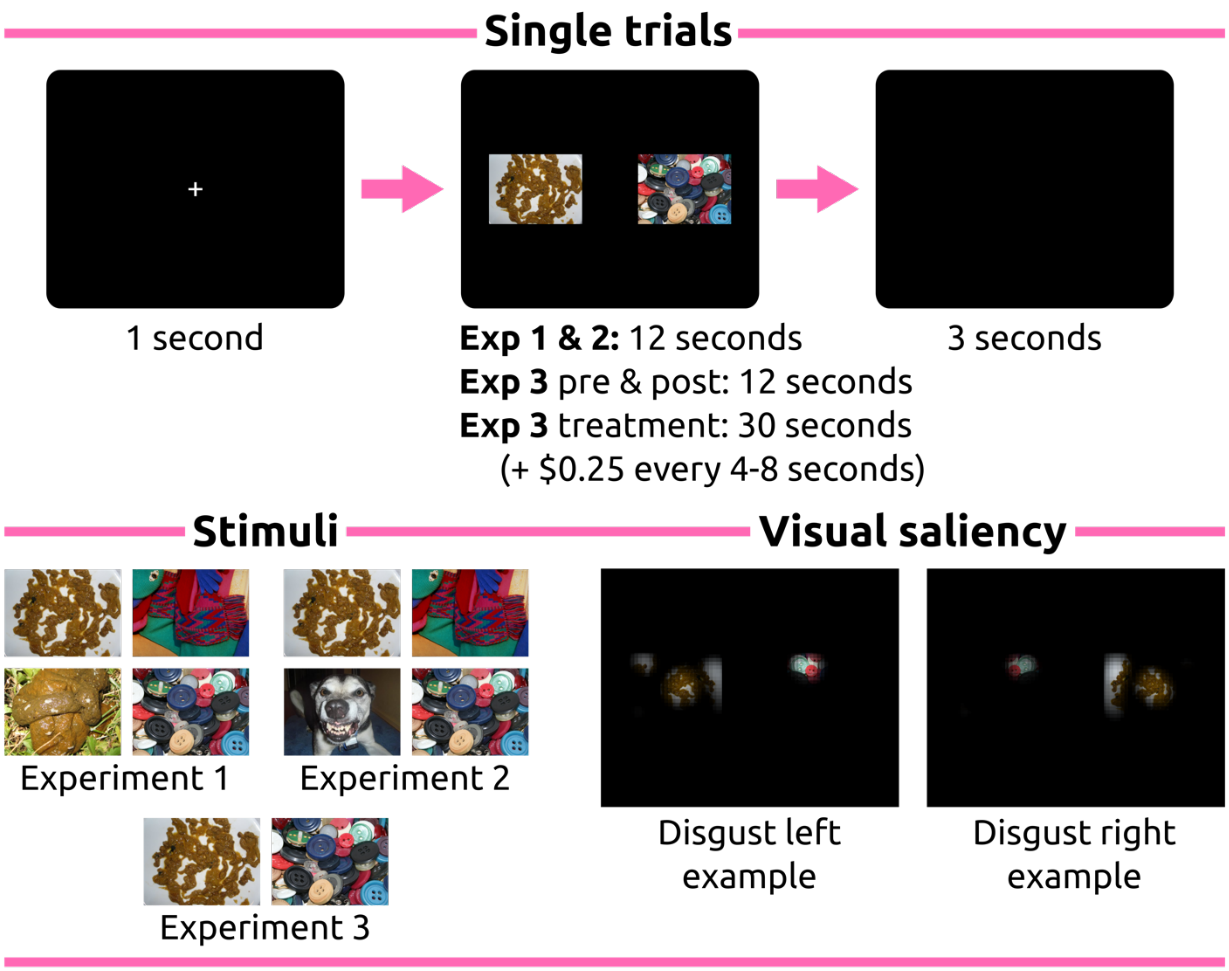

Figure 1. Overview of procedures and stimuli. Visual saliency based on a model by Itti, Koch, & Niebur (1998).

Apparatus. One Dell PC with a core i5 processor was used for both stimulus presentation and data acquisition. Stimuli were presented using OpenSesame software (Mathôt et al., 2012) at a viewing distance of 65 cm on a 22" (55.9 cm; 43.6 x 34.9 cm) monitor, operating at a refresh rate of 60 Hz, and with the screen resolution set to 1280 x 1024 pixels by OpenSesame. Eye movements were recorded by an Eye Tribe eye tracker (60 Hz; Copenhagen, Denmark) controlled by the PyGaze toolbox (Dalmaijer et al., 2014). Although the Eye Tribe is not designed specifically for research, it has been tested in comparison to research-grade eye trackers, and it has been shown to be comparable in performance for measuring dwell time (Dalmaijer, 2014).

Procedure. Participants provided informed consent to a protocol approved by the Whitman College Institutional Review Board. They completed a demographic survey and the DS-R on paper, and then completed the habituation task on the computer. The habituation task had two blocks with different stimulus pairs, and each block had 24 trials. Each trial consisted of a 1 s fixation cross, followed by a 12 s presentation of the stimulus pair, followed by a 3 s inter-trial interval consisting of a blank screen (Figure 1). Self-report ratings of the stimuli were provided before (pre-exposure), halfway through (mid-exposure), and after (post-exposure) each block. The side on which the disgusting or neutral image was presented was counterbalanced and randomized for each sub-block of 12 trials. The eye tracker was calibrated using a 9-point procedure at the beginning of each block.

Data reduction and analysis. For every trial, we computed the combined duration of all gaze samples within each area of interest (AOI): disgust stimulus, neutral stimulus, and elsewhere on the screen ("other"). These dwell times per AOI were then divided by the total dwell time (which did not include missing data) to produce the proportion of time participants gazed at each stimulus.

We subjected the dwell time proportions for neutral and disgusting stimuli to linear mixed effects analyses, using participant number as a random factor. In one model, we incorporated stimulus type (disgust, neutral) and block (first, second) as dichotomous factors, trial number (1-24) as continuous; and incorporated a stimulus-by-trial interaction to test for changes in disgust avoidance. In a second model, we incorporated only stimulus type and trial number (1-48; ignoring block), and again a stimulus-by-trial interaction. To investigate trial-level oculomotor disgust avoidance, we tested for differences in dwell time proportion for neutral and disgusting stimuli in each trial, using related-samples t-tests and Holm-Bonferroni correction for multiple comparisons (Holm, 1979).

Self-reported arousal, disgust, and pleasantness ratings were analysed separately, again using linear mixed effects models. One included stimulus (disgust, neutral), block (first, second), and moment (pre-trials, mid-trials, post-trials) as categorical factors, and a stimulus*moment interaction to test for changes in ratings. A second model dropped block as a factor, but was otherwise unchanged. To test for differences in ratings between the start and end of each block, we employed related-samples t-tests on the pre-trials and post-trials ratings.

Because some gender differences have been reported for disgust sensitivity (Tybur et al. 2011), we also ran the above models while including self-reported gender as a dichotomous factor (woman vs. man; no participants reported other gender identities). Incorporating gender was a post-hoc decision prompted by a reviewer, and not within the main scope of the current study. Results are thus reported separately in the Supplementary Materials.

Model fit was determined using the Bayesian Information Criterion (BIC), interpreted according to Raftery's guidelines (Raftery, 1995), with ΔBIC values of 2-6 constituting positive evidence, 6-10 strong evidence, and over 10 very strong evidence for the model with the lowest BIC.

Whether model parameter estimates were significantly different from 0 was determined using one-sample t-tests. Absences of meaningful differences from 0 were tested using TOST equivalence testing with bounds set to $d = .3$ and $d = -.3$ (Lakens, 2017).

Effect sizes were quantified as Cohen's d, which was computed subtly differently for parameter estimates in linear mixed effects (Equation 1) and related-samples t-tests (Equation 2).

(1) $$d = \frac{\beta}{s}$$

Where β is the standardized coefficient, and s the standard deviation (computed as the product of the standard error and the square root of the sample size).

(2) $$d = \frac{\left| m_1 - m_2 \right|}{\sqrt{s_1^2 + s_2^2 - \left(2 r s_1 s_2\right)}}$$

Where m_1 and m_2 are the means and s_1 and s_2 standard deviations of participants for conditions 1 and 2, and r is the Pearson correlation coefficient between conditions 1 and 2.

Missing data. Trials with over 50% invalid data were marked as missing (318 from 52 participants). For linear mixed effects analyses, 8 participants with more than 30% missing trials were excluded (leaving a total N of 95), and other missing data was imputed using 5-nearest neighbors. Dropping cases with missing data, an alternative approach, resulted in the same outcomes. For post-hoc t-tests, trials with missing data were dropped for each t-test independently, resulting in slight differences in degrees of freedom between the tests. This method ensured that all trials with 50% or less invalid gaze data could be incorporated.

Open Materials. All experiments, data, and analyses materials have been made publicly available through the Open Science Framework at https://osf.io/7gkmu/

Results

The first experiment yielded both eye movement and self-report data. Dwell time proportions for two areas of interest were recorded in a 2x2x24 experimental design: stimulus type (disgust, neutral), block (first, second), and trial number (1-24). Self rating data on three scales (arousal, disgust, pleasantness) was recorded in a 2x2x3 design: stimulus type (disgust, neutral), block (first, second), and time-in-block (pre-, mid-, and post-trials).

Eye movement data.

The outcomes of a linear mixed model of dwell time proportion that incorporated participant number as random effect; stimulus, block, and trial number as main effects; and interaction effect stimulus by trial are reported in Table 1. There was a significant main effect of stimulus, indicating that participants looked at the neutral stimulus more than the disgusting stimulus. Main effects of block and trial suggest that dwell times varied between trials, perhaps as a consequence of participants looking at neither stimulus. There was no significant interaction between stimulus and trial, and in fact at an uncorrected level it was significantly (p=0.035) equivalent to no meaningful effect.

Further models are described in the Supplementary materials (Tables S1.1 – S1.5), including a better fitting model that incorporated gender. However, none of the gender terms significantly related to dwell time proportion, and many were statistically equivalent to a lack of an effect.

Table 1 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), block (first vs. second), and trial (1-24). Reported for each parameter are the standardized coefficient (β) and its 95% confidence interval, and the associated one-sample t test results (t and p). Also reported are the results of a two one-sided tests (TOST) procedure to test for statistical equivalence (sub-threshold p values indicate equivalence). Bonferroni-corrected significant p values are marked in bold.*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.49	-0.57	-0.40	-10.88	**<0.001**	-7.94	1.000
Stimulus (reference disgust)	0.52	0.48	0.55	27.16	**<0.001**	24.22	1.000
Block (reference first)	0.15	0.12	0.19	8.03	**<0.001**	5.09	1.000
Trial	-0.04	-0.06	-0.01	-2.68	**0.009**	0.26	0.397
stimulus * trial	0.02	-0.02	0.06	1.11	0.271	-1.83	0.035

As revealed in Figure 2, the difference between dwell time proportion for disgusting images and neutral images (averaged across both blocks) was statistically significantly different from 0 in all but trials 1 (first trial) [$t(102)=2.12$, $p=0.036$, $d=0.21$] and 13 (first trial after mid-block questions) [$t(99)=1.89$, $p=0.061$]. For all other trials, t values ranged from 2.60 to 5.13, associated p values from 0.011 to 0.000001, and d values from 0.26 to 0.51, and were considered statistically significant after Holm-Bonferroni correction (Holm, 1979).

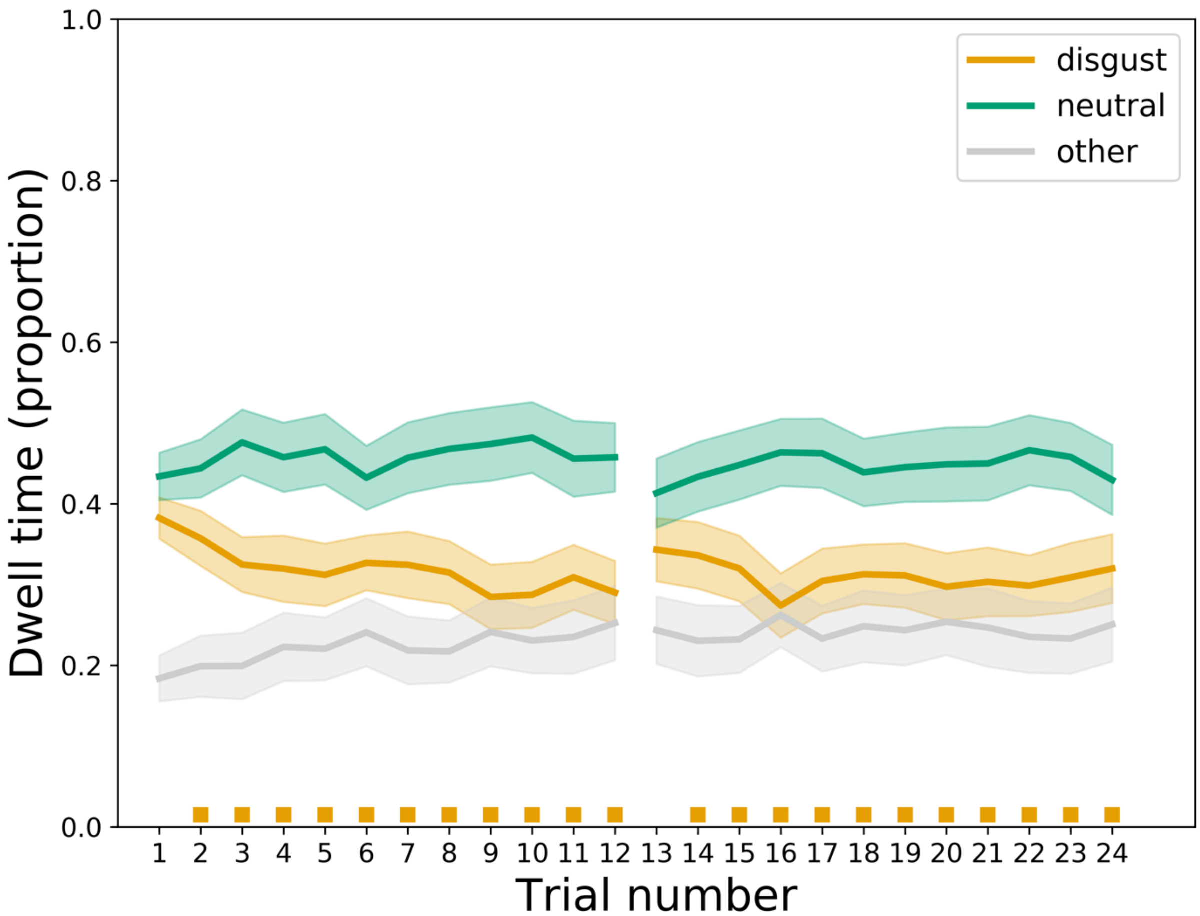

***Figure 2**. Dwell time on stimuli across exposures in Experiment 1. Note: break in lines represents mid-point ratings; dwell times are averages for both blocks, and shading indicates the within-participant 95% confidence interval; orange squares mark trials with p < .05 on a paired-samples t-test for disgust and neutral dwell time (Holm-Bonferroni corrected for 24 comparisons); "other" refers to dwell on non-stimulus regions of screen.*

Self-report data.

Participants provided arousal, disgust, and pleasantness ratings for all stimuli used in the experiments. They did so at three different moments: Before viewing the stimulus pair, after 12 trials of the stimulus pair, and after 24 trials of the stimulus pair. Linear mixed effects models were fit to all three rating outcomes, using participant number as a random effect; main effects gender (woman or man; no other genders reported), stimulus (disgust or neutral), block (first or second), and moment (pre, mid, and post); and interaction effects depending on the included factors. Models of arousal and pleasantness ratings, and those including gender as predictor, are reported in the Supplementary Materials.

The best fitting model (ΔBIC=11.7 for the second-best) showed significant main effects of stimulus [β=-1.57, 95% CI [-1.68,-1.47], $t(102)=-29.16$, $p<0.001$; TOST $t(102)=11.48$, $p=1.000$] and moment [β=-0.13, 95% CI [-0.19,-0.07], $t(102)=-4.45$, $p<0.001$; TOST $t(102)=-1.40$, $p=0.0918$], and a significant interaction between them [β=0.21, 95% CI [0.13,0.29], $t(102)=5.00$, $p<0.001$; TOST $t(102)=1.96$, $p=0.973$]. An equally-well fitting model that (including gender, stimulus, and their interaction) is reported in the Supplementary Materials.

These results indicate that participants reported experiencing more disgust in response to the disgusting image compared to the neutral image, and this difference changed over the course of exposure to a stimulus pair. Prior to exposure, participants reported feeling between "mildly" and "moderately" disgusted (just over 40 on the unipolar empirical valence scale). After 24 trials of exposure, participants reported feeling less disgusted by the disgust stimulus by an average of 7 points on the 100-point scale [$t(102)=-3.84$, $p<0.001$, $d=-0.38$], but not more pleasant [$t(102)=1.58$, $p=0.116$]. Although statistically significant, this may not represent a practically significant reduction given that scores before and after exposure both correspond to feeling "mildly" to "moderately" disgusted. Curiously, participants reported experiencing more disgust [$t(102)=3.58$, $p<0.001$, $d=0.35$] and less pleasantness [$t(102)=-2.70$, $p=0.008$, $d=0.27$] to the neutral stimulus following the 24 trials of exposure, but again the change was small (about 4 points). In sum, disgust ratings dropped for the disgusting stimulus, but increased for the neutral stimulus, perhaps due to associative learning (see Figure 3).

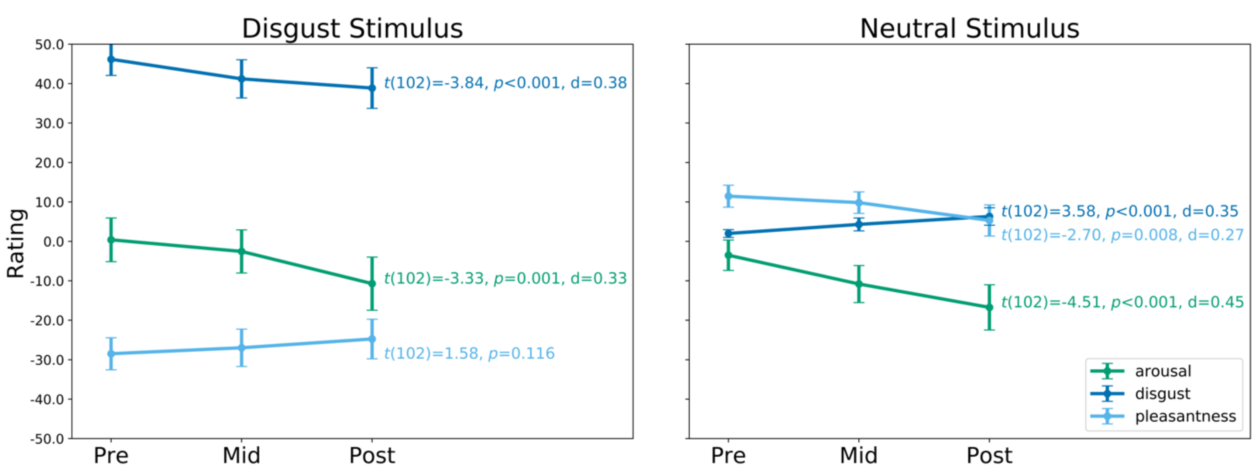

Figure 3. *Self-reported affect in response to stimuli at multiple stages of exposure in Experiment 1. Error bars indicate within-participant 95% confidence intervals. Annotated test statistics are for related-samples t-tests between the pre- and post-block ratings, and are not corrected for multiple comparisons.*

Reliability.

We computed the test-retest reliability by computing the intraclass correlation (Bartko, 1966) and Pearson correlation between the two blocks for participants' self-reported disgust (at the start of a block) and for their average oculomotor disgust avoidance (neutral minus disgust dwell time on each trial, averaged across trials within a block). The results show that self-reported disgust [ICC=0.59, R=0.61, p<0.001] is equally reliable to oculomotor avoidance [ICC=0.57, R=0.59, p<0.001]. These results indicate that, even when using different stimuli, self-reported disgust ratings and neutral-disgust dwell time difference are both reliable measures.

Correlations between eye movement data, self-report data, and disgust proneness.

Oculomotor avoidance of disgusting stimuli (neutral-disgust dwell time difference) was statistically significantly correlated with disgust proneness (trait disgust as measured with the DS-R) [R=0.28, p=0.004]. Although oculomotor avoidance was also correlated with state disgust (self-report before block onset) [R=0.28, p=0.004], after regressing out DS-R scores, there was no longer a significant correlation between oculomotor disgust and residual disgust rating [R=0.15, p=0.144].

Discussion

In Experiment 1, we found that oculomotor avoidance of a disgusting image is not attenuated by repeated exposure, in line with the hypothesis that disgust resists habituation. Repeated exposure to one disgusting stimulus also did not appear to facilitate habituation of oculomotor avoidance to a second disgusting stimulus. Self-reported disgust did show habituation, but it was subtle. Oculomotor avoidance correlated with both self-reported disgust to the images and disgust proneness, evidence of convergent validity, and had moderate test-retest reliability between blocks. However, one limitation of Experiment 1 is that it did not assess other negative affective stimuli.

Experiment 2

In Experiment 2, we sought to determine if oculomotor avoidance is specific to disgusting stimuli and if disgust habituates more slowly compared to fear. The procedure for Experiment 2 was the same as in Experiment 1, but in one of the blocks, the disgusting image was replaced with a frightening image. Block order and neutral stimulus pairing were randomly counterbalanced. We predicted that only disgust would be characterized by oculomotor avoidance and that any oculomotor response to fear would attenuate across exposures.

Participants. An unselected sample of students (*N* = 99, age in years *M*=19.3, *SD*=1.36, min=17, max=24; 25% men, 75% women; 62% White, 1% Black, 5% Hispanic or Latino/a, 18% Asian (including 1% Indian), 1% native American, 1% native Hawaiian, 1% Middle Eastern, 11% multiracial) at a Northwest private college completed the experiment for extra credit in a psychology course or a $10 gift card.

Materials. An image of a restrained dog bearing its teeth and trying to attack was selected as the fear stimulus (Figure 1). This image was selected from a larger sample of attacking dogs used in (Armstrong et al., 2013) because it elicited a high amount of fear and a low amount of disgust in the self-report ratings in this prior study. One of the disgusting images with higher disgust ratings and the two neutral images from Experiment were the other stimuli.

Missing data. The same approach was taken as for experiment 1, resulting in 249 trials (from 22 participants) with over 50% invalid data were marked as missing. As a consequence, 8 participants were excluded from linear mixed effects analyses, leaving a total N of 91.

Results

The second experiment again yielded both eye movement and self-report data. Dwell time proportions for two areas of interest were recorded in a 2x2x24 experimental design: stimulus type (affective, neutral), block (disgust, fear), and trial number (1-24). Self-report rating data on four scales (arousal, disgust, fear, pleasantness) was recorded in a 2x2x3 design: stimulus type (affective, neutral), block (disgust, fear), and time-in-block (pre-, mid-, and post-trials).

Eye movement data.

As for experiment 1, linear mixed models with participant as random effect were fit to the data. Included factors were self-reported gender (women or man; no other options reported), stimulus type (affective or neutral), block type (disgust or fear), and trial number (1-24).

The best fitting model that did not include gender (ΔBIC=22.8 for the second-best model without gender) is summarized in Table 2. It shows statistically significant main effects of stimulus and block, and a significant interaction between them. These results indicate that dwell time proportions were higher for neutral compared to affective stimuli, higher in the disgust compared to the fear block, and more different between the affective and neutral stimulus in the disgust block compared to the fear block.

Further models are described in the Supplementary materials (Tables S2.1 – S2.4). This includes a better fitting model (Table S2.4) that incorporated gender, and showed an interaction effect of gender by stimulus.

Notably, the best-fitting models did not include the factor trial. This suggests that trial was not a particularly relevant factor, likely because dwell times were rather constant across trials (Figure 4). A worse-fitting model that did include trial (Table S2.1) showed a main effect and an interaction effect with stimulus, reflecting the increase in affection avoidance in the disgust block. These results illustrate an overall lack of habituation, and if anything an increase in avoidance. Further post-hoc tests (included below and in Figure 4) show that this is driven by the sustained difference in dwell time between disgusting and neutral stimuli after the first trial, and a lack of a such a difference between dwell times for fear and neutral stimuli after the first trial.

Table 2 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), block (first vs. second), and trial (1-24). Reported for each parameter are the standardized coefficient (β) and its 95% confidence interval, and the associated one-sample t test results (t and p). Also reported are the results of a two one-sided tests (TOST) procedure to test for statistical equivalence (sub-threshold p values indicate equivalence). Bonferroni-corrected significant p values are marked in bold.*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.43	-0.49	-0.37	-14.91	**<0.001**	-12.05	1.000
Stimulus (reference affective)	0.85	0.80	0.91	30.25	**<0.001**	27.39	1.000
Block (reference disgust)	0.53	0.47	0.58	18.64	**<0.001**	15.78	1.000
stimulus * block	-1.03	-1.11	-0.95	-25.89	**<0.001**	-23.03	1.000

The difference between dwell time proportion for disgusting images and neutral images was statistically significantly different from 0 in all but trials 1 [$t(97)=1.74$, $p=0.085$] and 2 [$t(97)=1.61$, $p=0.111$]. For all other trials, t values ranged from 3.08 to 5.92, associated p values from 0.003 to 0.00000006, and d values from 0.32 to 0.63, and were considered statistically significant after Holm-Bonferroni correction (Holm, 1979). These data show that participants showed oculomotor avoidance of disgust in all trials, with the exception of the first two (Figure 4).

The difference between dwell time proportion for fear-eliciting images and neutral images was statistically significantly different from 0 only in trial 1 [$t(97)=-4.09$, $p=0.00009$, $d=-0.41$], with greater dwell on the fear-eliciting image. For all other trials, t values ranged from -2.89 to -0.12 (and to 1.93), and associated p values from 0.005 to 0.908 (and 0.056), and were not statistically significant after Holm-Bonferroni correction (Holm, 1979). These data show that participants show oculomotor approach of fear in the first trial, but no statistically significant preference for either stimulus in all following trials (Figure 4).

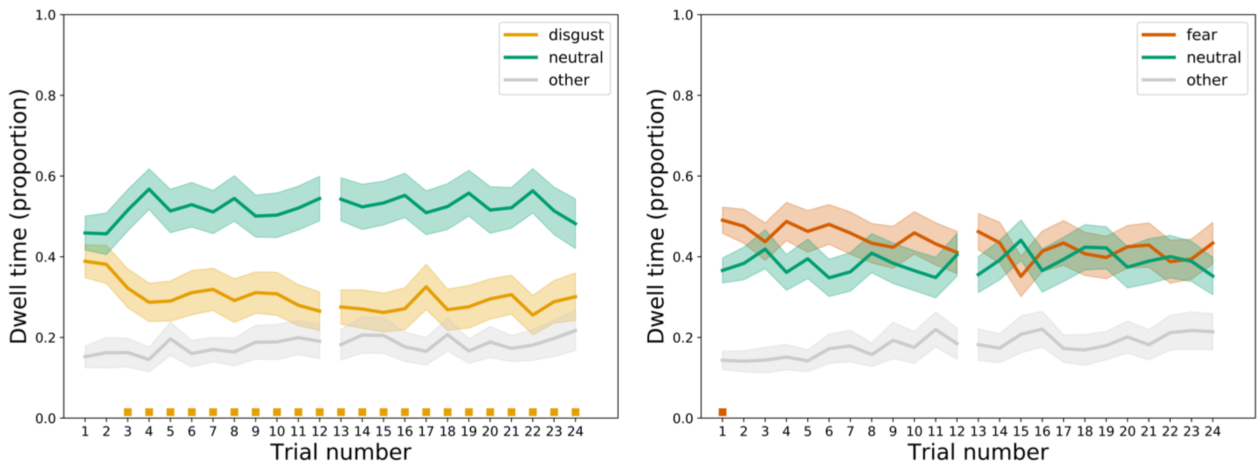

Figure 4. *Dwell time on stimuli across exposures in Experiment 2. Note: break in lines represents mid-point ratings; dwell times are average across participants, with shaded areas indicating within-participant 95% confidence intervals; orange squares mark trials with p < .05 on a paired-samples t-test for disgust and neutral dwell time (Holm-Bonferroni corrected for 24 comparisons); "other" refers to dwell on non-stimulus regions of the screen.*

Self-report data.

A linear mixed effects analysis (Table S2.5) of disgust ratings was conducted with participant number as random effect, main effects stimulus (fear, neutral control for fear, disgust, and neutral control for disgust) and moment (pre-, mid-, and post-trials), and interaction effect stimulus by moment. A main effect of moment showed that disgust ratings reduced over the course of a block, and main effects of stimulus showed that disgust ratings were higher for the disgusting stimulus compared to all other stimuli. Interaction effects of stimulus and block showed that disgust ratings for disgusting stimuli reduced more over the course of a block compared to disgust ratings for other stimuli. Incorporating gender into the model produced a far worse fit (ΔBIC=55.8).

A linear mixed effects analysis for fear ratings (Table S2.6) similarly showed main effects of stimulus, but not of moment, and only a significant interaction between moment and disgusting and fear stimuli. This suggests that participants rated the disgusting stimulus as more fear-eliciting than the neutral stimuli, but less so than the fear stimulus. In addition, the reduction in fear rating was stronger for the fear stimulus compared to that for the disgust stimulus.

As for experiment 1, models with arousal and pleasantness ratings as outcomes, and those including gender as predictor, are reported in the Supplementary Materials.

Self-reported disgust ratings were significantly different between the pre- [*M*=48.94, *SD*=23.45] and post-block [*M*=37.59, *SD*=28.61] measurement for the disgusting stimulus [*t*(98)=-3.76, *p*<0.001, *d*=0.38]. Self-reported fear ratings for the fear-eliciting stimulus reduced between pre [*M*=32.81, *SD*=23.65] and post [*M*=18.82, *SD*=22.77] measurement [*t*(98)=-5.95, *p*<0.001, *d*=0.60].

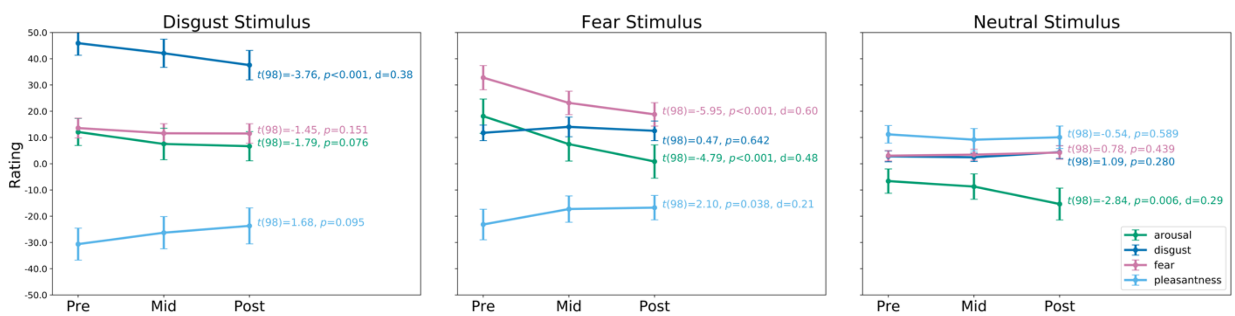

Figure 5. *Self-reported affect in response to stimuli at multiple stages of exposure in Experiment 2. Error bars indicate within-participant 95% confidence intervals. Annotated test statistics are for related-samples t-tests between the pre- and post-block ratings, and are not corrected for multiple comparisons. The plotted neutral stimulus is the average of both neutral stimuli used as controls in the disgust and the fear blocks.*

Correlations between eye movement data, self-report data, and disgust proneness.

As in experiment 1, trait disgust (DS-R) was significantly correlated with oculomotor disgust avoidance, as revealed by the neutral minus disgust dwell time difference [*R*=0.34, *p*<0.001].

Oculomotor disgust avoidance was not associated with stimulus disgust ratings [R=0.14, p=0.154], nor with disgust ratings after regressing out DS-R). [R=-0.02, p=0.826]. Oculomotor fear avoidance, as revealed by the dwell time difference for neutral minus fear stimuli was not correlated with DS-R score [R=0.09, p=0.355], fear ratings [R=0.15, p=0.135], or fear rating after regressing out DS-R scores [R=0.13, p=0.197]. These results indicate that participants' oculomotor disgust avoidance was correlated with their disgust proneness (DS-R score), but not with their ratings of the disgusting stimulus. Gaze behaviour for the fear stimulus was not related with DS-R score, nor with fear ratings.

Discussion

In Experiment 2, we replicated the finding from Experiment 1 that repeated exposure does not attenuate oculomotor avoidance of a disgusting image. As predicted, this pattern of oculomotor responding was specific to disgust, and was not observed for fear. We did not observe significantly different slopes in changes in dwell time on disgusting versus fear-eliciting images across trials; however, we did find that the fear-eliciting image was viewed more, compared to the accompanying neutral image, on just the very first trial, suggesting that oculomotor responding to fear stimuli may habituate rapidly. The self-report data did not provide clear evidence that disgust habituates more slowly than fear (Rouel et al., 2018). Although we cannot make strong conclusions regarding the habituation of disgust versus fear, the results of Experiments 1 and 2 clearly suggest that oculomotor avoidance of disgusting stimuli is not prone to habituation.

However, it is possible that disgust does not habituate as quickly in free viewing paradigms because oculomotor avoidance undermines the effects of exposure. Habituation to a visual stimulus is thought to occur through the development of a neural representation of the stimulus in the thalamus or visual cortex following repeated sensory input (Bradley et al., 2003.; Sokolov, 1963). By looking away from the disgusting image, participants limited sensory input, which could have undermined habituation.

Experiment 3

In Experiment 3, we addressed this potential effect of oculomotor avoidance on habituation by motivating participants to look at the disgusting stimulus with a reward. We created a gaze-contingent operant conditioning procedure in which participants received money for maintaining gaze on the disgusting stimulus, as indicated by a sound. We assessed dwell time on the disgusting stimulus before, during, and after the treatment. We predicted that the treatment would succeed in ensuring perceptual contact during exposure, but would not reduce oculomotor avoidance from pre- to post-treatment assessment, in line with the findings of Experiments 1 and 2.

Methods

Participants. An unselected sample of students (N = 93; age in years M=19.6, SD=1.19, min=18, max=22; 46% men, 54% women; 77% White, 1% Black, 6% Hispanic or Latino/a, 16% Asian) at a Northwest private college completed the experiment for extra credit in a psychology course or $10.

Measures and materials. Participants completed the DS-R (Olatunji et al., 2007). In Experiment 3, disgust ratings of the images were collected using a slider controlled by the mouse on a scale that ranged from "not at all" to "most imaginable." One of the image pairs from Experiment 1 was selected for this experiment. The images were presented in the same size and location described in Experiment 1.

Apparatus. The same apparatus was used in Experiment 3. However, the experiment was controlled by a custom Python script (Dalmaijer, 2016) instead of OpenSesame.

Procedure. Participants provided informed consent to a protocol approved by the Whitman College Institutional Review Board. Then they completed a demographics survey and the DS-R on the computer. Next, they completed the pre-treatment assessment of oculomotor avoidance, which included 10 trials. The trials were the same as those in Experiment 1, consisting of a 1 s fixation cross, followed by a 12 s presentation of the disgusting and neutral image, followed by a 3 s inter-trial interval. Participants then underwent the treatment, which included 10 trials, each consisting of a 1 s fixation cross, followed by a 30 s presentation of the disgusting and neutral image, followed by a 3 s inter-trial interval. Prior to the treatment, participants were instructed "You will earn money for looking at the unpleasant image (the poop). When you are looking at the unpleasant image and you hear a sound, it means you have earned $.25. If you look at the unpleasant image as much as you can, you can earn $10 in the next section." During each 30 s presentation of the images, dwell time on each image was calculated online. A random value was selected between 4000 ms and 8000 ms as the reward criterion, and when dwell time on the disgusting image reached the selected value, the participant heard a sound indicating the reward. Then a new random value was selected, the dwell time counter was reset, and the process was repeated until the end of the trial, at which point the participant was notified how much they earned on the trial. A variable reward schedule was selected to make the task more engaging. Following the treatment, participants completed a post-treatment assessment of oculomotor avoidance, which was identical to the pre-treatment assessment. Participants also completed self-report ratings of the stimuli immediately before and after the treatment.

In total, the described design included 5 minutes of reward-encouraged disgust viewing, which corresponds to the duration of experiments 1 and 2. Given the highly exploratory nature of this experiment, we were unable to establish a priori whether this was a sufficient exposure time. Given the clear findings of Experiments 1 and 2 showing no habituation without encouraged exposure, we decided against including a non-rewarded control condition to save resources.

Data analysis. In this experiment, the main question was whether reward-encouraged exposure to a disgusting stimulus would reduce further disgust avoidance. To formally test for this, we employed the same models as in experiments 1 and 2, but also simpler versions that did not include block or did not include block and trial as factors (both in main effects, and part of interaction effects). If the simpler models fitted the data better, this would be evidence against an effect of block, and thus a lack of a difference between pre- and post-treatment disgust avoidance.

Missing data. The same approach was taken as for experiments 1 and 2, resulting in 47 trials (from 15 participants) with over 50% invalid data were marked as missing. No participants were excluded from linear mixed effects analyses, as none showed more than 30% missing trials, leaving a total N of 95.

Results

While the design of the third experiment was set up as a 2x3x10 design for stimulus type (disgust, neutral), block (pre-treatment, treatment, and post-treatment), and trial number (1-10); it was analyzed as 2x2x10 (pre- and post-treatment differences) and 2x1x10 (manipulation check).

Eye movement data

Manipulation check. Rewarding participants for looking at the disgusting stimulus completely reversed the disgust avoidance observed in experiments 1 and 2, with participants looking at the disgusting stimulus on average around 90% of the trial. During the treatment, the difference between dwell time proportion for disgusting and neutral images was statistically significantly different from 0 in all 10 trials [all t in [-39.00, -27.29], all df in [93, 95], all p in [7.59e-60, 1.01e-38], all d in [-4.02, -2.81]]. These particularly strong results indicate that the reward contingency was highly effective in motivating participants to look at the disgusting image, rather than avoid it.

Treatment effects. Because we were interested in the treatment effect (i.e. pre-post difference) on oculomotor disgust avoidance, we did not include the data from the treatment phase in the next analyses. Three models were fitted: The first tested main effects of factors stimulus, phase, and trial, and all their interactions; the second tested main effects of stimulus and trial, and their interaction; and the last tested only the main effect of stimulus. The best fitting model was the third and simplest, and convincingly so with ΔBIC=12.4 for the second model, and ΔBIC=52.1 for the first. The main effect of stimulus was statistically significant [β=0.57, 95% CI=[0.51,0.63], $t(95)=18.87$, $p<0.001$; TOST $t=15.93$, $p=1.000$], indicating that participants looked at the neutral stimulus for longer than the disgusting stimulus.

The fact that the best-fitting model did not include the factor “phase”, is in itself evidence against a difference between pre- and post-treatment blocks. This is further illustrated by results from worse-fitting model that did include this factor, which show that the interaction between phase and trial [β=0.02, 95% CI=[-0.07,0.10], $t(95)=-0.39$, $p=0.698$; TOST $t=-2.55$, $p=0.006$], and between stimulus, phase, and trial [β=-0.02, 95% CI=[-0.14,0.10], $t(95)=-0.32$, $p=0.751$; TOST $t=2.62$, $p=0.005$] were equivalent to no effect (see Supplementary Materials for full details).

As before, models including gender were fitted. While fitting the data better, the only effect they showed is a larger difference in dwell time proportions between disgusting and neutral stimuli in women compared to men. Notably, this effect only occurs in the worst-fitting model (Table S3.4), but not in the second-best fitting model (Table S3.5), nor in the best-fitting model (Table S3.6). The latter only included gender, stimulus, and their interaction, and demonstrated a main effect of stimulus, and a clear lack of an effect of gender, and lack of an interaction. In sum, participants avoided disgusting stimuli before and after reward-encouraged exposure, and this was the same across genders.

The difference between dwell time proportion for disgusting images and neutral images was statistically significantly (after Holm-Bonferroni correction for multiple comparisons) different from 0 in pre-treatment trials 3, 4, 7, 8, and 9 (t in [2.82, 3.94], p in [0.000156, 0.00592]. d in [0.29, 0.41]), but not in the other pre-treatment trials (t in [1.36, 2.65], p in [0.00950, 0.176]). In the post-treatment trials, the difference between dwell time proportion for disgusting and neutral images was statistically significantly different from 0 in trials 2-10 (t in [3.38, 4.86], p in [0.00000500, 0.00107]. d in [0.35, 0.51]), but not in trials 1 [$t(95)$=0.70, p=0.488] and 5 [$t(94)$=2.34, p=0.02131, d=0.24]. Note that statistical significance is considered after Holm-Bonferroni correction (Holm, 1979) for *all* 30 trials (10 pre-treatment plus 10 treatment plus 10 post-treatment). Uncorrected, only dwell differences in pre-treatment trials 1 and 2 and post-treatment trial 1 would be considered non-significant. These data show that participants showed oculomotor avoidance of disgust in the pre-treatment phase. By contrast, participants showed strong disgust approach during the reward treatment (over 80% of dwell time on the disgust stimulus in all trials). However, participants showed disgust avoidance again in the post-treatment phase (Figure 6).

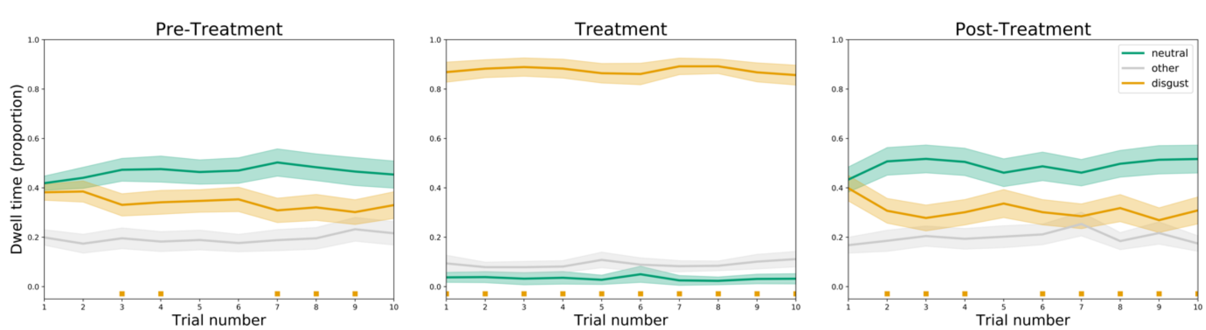

Figure 6. *Dwell time on stimuli across stages in Experiment 3. Reported dwell times are averages across participants, with shaded areas indicating within-participant 95% confidence intervals; orange squares mark trials with p < .05 on a paired-samples t-test for disgust and neutral dwell*

time (Holm-Bonferroni corrected for 30 comparisons); "other" refers to dwell on other regions of screen.

Self-report data.

As for dwell time, the best-fitting linear mixed models for ratings did not include phase (see Supplementary Materials for model parameters and fit indices). While this suggests ratings were not impacted by treatment, the difference in fit was not particularly high (e.g. ΔBIC=5.2 for disgust ratings) compared to models that showed a statistically significant interaction between stimulus type and phase. We thus elected to compute post-hoc related-samples t-tests on the difference in ratings between the pre- and post-treatment phases..

From pre- to post-treatment, participants reported feeling significantly less disgusted [$t(92)=4.18$, $p<0.001$, $d=0.43$] and less unpleasant [$t(92)=-4.40$, $p<0.001$, $d=0.45$] in response to the disgusting image, but they did not change their arousal ratings [$t(92)=0.54$, $p=0.591$]. From pre- to post-treatment, participants did not report feeling significantly different in response to the neutral image, in terms of disgust [$t(92)=-0.70$, $p=0.483$], pleasantness/unpleasantness [$t(92)=1.82$, $p=0.072$], or arousal [$t(92)=-0.81$, $p=0.422$] (Figure 7).

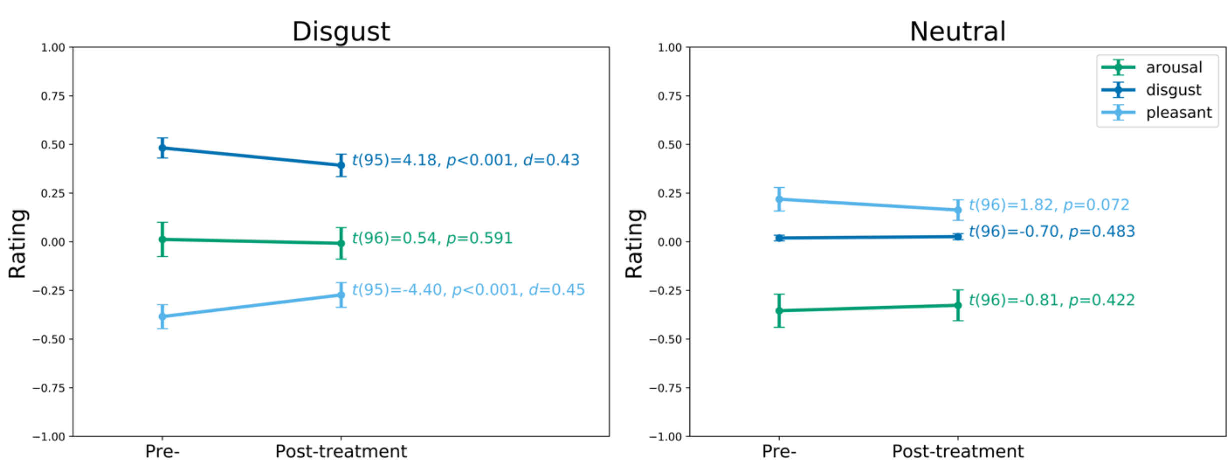

Figure 7. *Self-reported affect in response to stimuli at multiple stages of exposure in Experiment 3. Error bars indicate within-participant 95% confidence intervals. Annotated test statistics are for related-samples t-tests between the pre- and post-treatment ratings, and are not corrected for multiple comparisons.*

Correlations between eye movement data, self-report data, and disgust proneness.

To assess the effect of our motivated exposure treatment, we examined whether there were differences in which variables predicted oculomotor avoidance across the pre-treatment, treatment, and post-treatment blocks. For the following analyses, our indicator of oculomotor avoidance was the average total dwell time on the neutral stimulus minus the average total dwell time for the disgust stimulus. The higher the value of this difference, the more oculomotor avoidance a participant showed. We computed residual disgust ratings for stimuli as the residual after linear regression of participants' DS-R score on participants' disgust ratings. The residual disgust metric relates to how disgusting a participant rates a stimulus with respect to how disgusting they would rate other stimuli. It is their relative disgust rating (which can differ between participants as a function of how disgusting they rate a stimulus compared to their own reference frame) rather than an absolute rating (which would be higher for participants who score higher on the DS-R).

In the 10 pre-treatment trials, disgust avoidance was statistically significantly [R^2=0.22, F(3,89)=8.21, p<0.001] related to DS-R total [t=2.69, p=0.009], pre-treatment residual disgust rating for the disgusting stimulus [t=2.48, p=0.015], and pre-treatment arousal rating for the disgusting stimulus [t=2.84, p=0.006]. This result suggests that participants who had a stronger tendency to avoid looking the disgust stimulus, were also more likely to have a higher disgust proneness, to find the disgust stimulus more disgusting, and to find the disgust stimulus more arousing.

In the 10 treatment trials, oculomotor avoidance was not [R^2=0.01, F(3,89)=0.21, p=0.882] related to DS-R total [t=0.68, p=0.499], pre-treatment residual disgust rating for the disgusting stimulus [t=0.26, p=0.793], and pre-treatment arousal rating for the disgusting stimulus [t=-0.37, p=0.713]. This result suggests that reward trumped all of the factors that previously related to oculomotor avoidance of the disgusting image.

In the 10 post-treatment trials, oculomotor avoidance was again statistically significantly [R^2=0.24, F(6,86)=4.42, p<0.001] related to DS-R total [t=3.71, p<0.001] and pre-treatment residual disgust ratings for the disgust stimulus [t=2.41, p=0.018], but no longer with pre-treatment arousal ratings for the disgust stimulus [t=0.93, p=0.355]. In addition, oculomotor avoidance was related to the post-pre treatment disgust rating difference for the disgust stimulus [t=3.04, p=0.003], but not the post-pre arousal rating for the disgust stimulus [t=0.22, p=0.824], nor was it related to the post-pre difference in dwell time [t=-0.05, p=0.964]. These results indicate that after the treatment, participants who showed higher oculomotor avoidance were still more likely to also score higher on DS-R and to report higher residual disgust ratings, but they were no longer more likely to report higher arousal ratings for the disgust stimulus.

Discussion

In Experiment 3, we succeeded in motivating participants to maintain perceptual contact with a disgusting image during repeated exposure, but again found no effect of repeated exposure on oculomotor avoidance of disgust and only a small effect on self-reported disgust. As predicted, once the reward contingency was removed, oculomotor avoidance of the disgusting stimulus returned to pre-treatment levels. Also, we again found that oculomotor avoidance correlates with self-reported disgust to the stimulus and general disgust proneness, and in this study, oculomotor avoidance was uniquely related to both of these self-report facets of disgust.

General Discussion

In three experiments, we found that repeated exposure to a disgusting and neutral image pair did not reduce oculomotor avoidance of the disgusting image and had only a modest effect on self-reported disgust. Further, we ruled out the possibility that oculomotor avoidance of the disgusting image was preventing habituation by motivating perceptual contact in Experiment 3. In addition, Experiment 2 provided limited evidence that oculomotor responses associated with disgust habituate more slowly than those associated with fear. Finally, oculomotor avoidance exhibited good psychometric properties in terms of convergent validity with self-report measures of disgust (all three experiments), discriminant validity with a fear-eliciting stimulus (Experiment 2), and test-retest reliability (Experiment 1).

Our results are consistent with the hypothesis that disgust resists habituation during exposure, which has received mixed support in prior research. For example, Rouel and colleagues (2018) found that self-reported disgust did not decline across four time points during a behavioral task involving prolonged exposure to contaminants (e.g., used tissues), whereas self-reported fear of contamination and threat estimation did decline. However, some studies have observed declines in disgust following exposure. For example, Cougle and colleagues (2007) found that disgust declined substantially and at a rate similar to fear during analogue exposure treatment for subclinical OCD. Also, Rozin (2008) found that disgust to cadavers declined in medical students during a training rotation. In both of these studies, participants had prolonged contact with the disgusting stimuli (40 minutes; Cougle et al., 2007; 2-3 months; Rozin, 2008). While it is possible that more prolonged exposure would cause oculomotor avoidance of disgust to habituate, the complete lack of habituation on the present timescale, even with the treatment in Experiment 3, is striking.

It is also possible that repeated exposure only reduces disgust when participants actively engage with stimuli. For example, in Cougle and colleagues (2007) study, participants touched the contaminants and then touched themselves. In Rozin's (2008) study, participants dissected and explored the cadaver. One possibility is that disgust habituates more readily when there are multiple sensory inputs (e.g., haptic in addition to visual). Another possibility is that these tasks reduced disgust through a mechanism other than mere habituation. For example, disgust may be attenuated be a competing goal, such as performing well on a cadaver task (Rozin, 2008) or advancing in a hierarchically-structured exposure assignment (Cougle et al., 2007). Motivation towards a competing goal may reduce disgust directly, as has been observed for drives that compete with disgust (hunger, lust; see Tybur et al., 2013), or indirectly, perhaps by steering attention towards task completion and away from the disgusting aspects of a stimulus. Indeed, oculomotor avoidance of the disgusting image was dramatically reversed in Experiment 3 when it competed with the goal of earning money. This effect was transient: oculomotor avoidance returned when the competing goal ended. However, it is possible that in other contexts, in which goal activation is more chronic (e.g., medical school), motivation-based reductions in disgust could persist. Together, these findings highlight the importance of examining disgust modulators beyond biological drives (Tybur et al., 2013), as socially-constructed goals also appear capable of dampening disgust.

Finally, another source of discrepancy in studies on disgust habituation could be the dependent variables. Across three experiments, we found a subtle decrease in self-reported disgust, but not oculomotor avoidance. One possibility is that participants mislabel reductions in arousal as reductions in disgust, inflating disgust habituation on self-report measures (see Royzman et al., 2017). An alternative explanation is that reductions in self-reported disgust were simply a demand effect. In this interpretation, participants reported lower disgust ratings as experiments progressed because they presumed this was the experimenter's expectation, even if their actual level of disgust did not change (reflected in unchanging oculomotor disgust avoidance). Another possibility is that oculomotor avoidance is a deeply ingrained habit that persists after experienced disgust declines. Through its use as an emotion regulation strategy, oculomotor avoidance could be negatively reinforced with enough frequency that it becomes relatively independent of state affect (Wood & Rünger, 2016). Indeed, Experiments 1 and 2 found that oculomotor avoidance was related to disgust sensitivity, but not directly related to state disgust. However, Experiment 3 found a more direct relation between oculomotor avoidance and self-reported disgust, in line with a prior study (Armstrong et al., 2014). More research is needed to understand the precise relationship between oculomotor avoidance and the experience of disgust.

The present findings also contribute to the small literature on habituation to affective stimuli. Early preferential processing of affective stimuli appears mandatory (Codispoti et al., 2006) whereas automatic responses related to action preparation (e.g., skin conductance; Bradley et al., 2003) only occur for novel affective stimuli. In contrast to prior research, we examined the emotional modulation of sustained gaze, rather than early visual processing. We observed habituation of gaze towards the fear stimulus, as a bias towards the threatening dog was only observed for the first trial. Also, across experiments we found that oculomotor avoidance of the disgusting stimulus was *not* observed on the first trial, consistent with a prior study (Armstrong et al., 2019). On the first trial, there may be a fleeting tendency to thoroughly examine any novel, motivationally-relevant image (see also Kron et al., 2014), which may compete with the tendency to avoid disgusting images.

The present findings should be interpreted with multiple limitations in mind. First, because our goal was to maximize exposure to a stimulus, we used very few stimuli. It is unclear how well these findings would generalize to other disgust or fear stimuli (Yarkoni, 2019). Another limitation is the relatively brief duration of the exposure in this study compared to actual treatment. Despite these limitations, the present study offers a novel contribution to the disgust habituation literature and highlights the need to identify novel pathways for reducing disgust.

Context of the Research

This study builds on our prior work examining oculomotor avoidance as a conditioned disgust response. We found that oculomotor avoidance, as a conditioned disgust response, did not undergo extinction (Armstrong et al., 2014). We also found, unexpectedly, that oculomotor avoidance as an unconditioned disgust response *increased* with exposure, suggesting that it might not undergo habituation. In the present study, we sought to determine if disgust would resist habituation in the same manner that it resists extinction. Given our findings that disgust resists habituation, we are now conducting a series of studies to explore if disgust can be reduced through conceptual reorientation, which is not based in exposure. This study was important in establishing oculomotor avoidance as a valid, reliable measure of disgust that could be used to test theories and evaluate interventions. In addition, this study revealed that highly affordable commercial-grade eye trackers could be used to measure oculomotor avoidance using the PyGaze toolbox developed by the first author (Dalmaijer et al., 2014). We hope this study will inspire other researchers to employ eye tracking methods in their disgust research.

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Author contributions

T. Armstrong and E. S. Dalmaijer developed the study concept. All authors contributed to study design. Testing and data collection were performed by A. Lee, R. Leiter, and Z. Brown under the supervision of T. Armstrong. T. Armstrong and E. S. Dalmaijer analyzed the data, and drafted the manuscript. All authors commented on, and approved the final version of the manuscript for submission.

Open Practices Statement

The experiments described here were not pre-registered. All experiments, data, and analyses materials have been made publicly available through the Open Science Framework at https://osf.io/7gkmu/

Supplementary Materials

Forever Yuck: Oculomotor Avoidance of Disgusting Stimuli Resists Habituation

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Supplementary Methods

This supplement contains the results of additional mixed linear effects analyses. These fall apart into two categories: 1) Additional models that fit worse than the models reported in the main manuscript, and 2) Models than include self-reported gender as main effect and in interactions. The modelled outcome was dwell time proportion.

Significance testing. The tables reported here include standardised coefficients (β), their 95% confidence interval, and the associated *t* and *p* values. Low (sub significance threshold) *p* values indicate that the standardised coefficient is significantly different from 0. In the tables below, *p* values are printed in bold if they were statistically significant after Holm-Bonferroni correction.

Equivalence testing. In addition, the results of a two one-sided tests (TOST) equivalence procedure are reported. In this procedure, it is tested whether the coefficient is larger than a lower bound, and lower than a higher bound; which have been set to -0.3 and 0.3 in Cohen's *d* respectively. The reported values are the *t* value closest to 0, and the highest *p* value. For TOST, *p* values below the significance threshold provide evidence for the absent of a meaningful effect.

Supplementary Results – Experiment 1

Eye movement data. Table S1.1 provides the same information as Table 1 in the manuscript. The best-fitting model is described in Table S1.4, and includes gender. However, none of the gender terms significantly impact dwell time proportion, and in fact many are (before and some also after correction) statistically significantly equivalent to no effect.

***Table S1.1** – Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), block (first vs. second), and trial (1-24). Model BIC=24775.0*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.49	-0.57	-0.40	-10.88	**<0.001**	-7.94	1.000
Stimulus (reference disgust)	0.52	0.48	0.55	27.16	**<0.001**	24.22	1.000
Block (reference first)	0.15	0.12	0.19	8.03	**<0.001**	5.09	1.000
Trial	-0.04	-0.06	-0.01	-2.68	**0.009**	0.26	0.397
stimulus * trial	0.02	-0.02	0.06	1.11	0.271	-1.83	0.035

***Table S1.2** – Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), and trial (1-48, across both blocks). Model BIC=24787.0*

Parameter	*β*	*95% CI*		*t*	*p*	*TOST t*	*TOST p*
Intercept	-0.26	-0.33	-0.19	-7.48	**<0.001**	-4.54	1.000
Stimulus (reference disgust)	0.52	0.48	0.55	27.11	**<0.001**	24.18	1.000
Trial	0.02	-0.01	0.05	1.42	0.160	-1.52	0.066
stimulus * trial	0.07	0.03	0.11	3.60	**0.001**	0.66	0.746

***Table S1.3** – Outcomes of a mixed linear model using participant number as random factor. Included factor was stimulus (disgust vs. neutral). Model BIC=24800.5*

Parameter	*β*	*95% CI*		*t*	*p*	*TOST t*	*TOST p*
Intercept	-0.26	-0.33	-0.19	-7.48	**<0.001**	-4.54	1.000
Stimulus (reference disgust)	0.52	0.48	0.55	27.05	**<0.001**	24.11	1.000

***Table S1.4** – Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (women vs men; no other genders reported), stimulus (disgust vs. neutral), block (first vs. second), and trial (1-24). Model BIC=24609.0 (best fit)*

Parameter	*β*	*95% CI*		*t*	*p*	*TOST t*	*TOST p*
Intercept	-0.45	-0.55	-0.35	-8.95	**<0.001**	-6.01	1.000
Gender (reference female)	-0.10	-0.24	0.05	-1.31	0.194	1.63	0.053
Stimulus (reference disgust)	0.54	0.49	0.59	23.32	**<0.001**	20.38	1.000
Block (reference first)	0.15	0.11	0.19	7.86	**<0.001**	4.92	1.000
Trial	-0.03	-0.07	0.00	-2.11	0.037	0.83	0.205
gender * stimulus	-0.07	-0.15	0.01	-1.60	0.112	1.34	0.092
gender * trial	-0.01	-0.06	0.05	-0.18	0.857	2.76	**0.003**
stimulus * trial	0.02	-0.03	0.07	0.85	0.398	-2.09	0.020
gender * stimulus * trial	0.01	-0.07	0.09	0.23	0.822	-2.71	**0.004**

***Table S1.5** – Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (women vs men; no other genders reported), stimulus (disgust vs. neutral), and trial (1-48, across both blocks). Model BIC=24619.8.0*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.23	-0.31	-0.14	-5.45	**<0.001**	-2.51	0.993
Gender (reference female)	-0.10	-0.24	0.05	-1.31	0.194	1.63	0.053
Stimulus (reference disgust)	0.54	0.49	0.59	23.29	**<0.001**	20.35	1.000
Trial	0.01	-0.02	0.04	0.70	0.488	-2.24	0.014
gender * stimulus	-0.07	-0.15	0.01	-1.60	0.113	1.34	0.092
gender * trial	0.02	-0.03	0.08	0.84	0.405	-2.10	0.019
stimulus * trial	0.08	0.04	0.13	3.56	**0.001**	0.62	0.731
gender * stimulus * trial	-0.05	-0.13	0.03	-1.18	0.243	1.76	0.041

Self-report data. In addition to the linear mixed effects reported in the main manuscript, models for outcomes arousal and pleasantness, and models that included gender as a predictor were run.

Disgust ratings. An equally well-fitting model (ΔBIC=-0.2) compared to that reported in the main text showed statistically significant main effects of gender [β=-0.27, 95% CI [-0.47,-0.07], $t(102)=-2.67$, $p=0.009$; TOST $t(102)=0.37$, $p=0.0356$] and stimulus [β=-1.47, 95% CI [-1.55,-1.39], $t(102)=-35.52$, $p<0.001$; TOST $t(102)=-32.48$, $p=1.000$] on disgust ratings, as well as an interaction between the two [β=0.34, 95% CI [0.20,0.48], $t(102)=4.63$, $p<0.001$; TOST $t(102)=1.59$, $p=0.942$]. These results indicate that participants rated neutral images as less disgusting compared to disgusting images, that men rated disgust of all images lower than women, and that women were more likely to show a larger difference between their disgust rating of neutral and disgusting images.

Pleasantness ratings. The best fitting model for pleasantness ratings included only stimulus type, and showed a significant main effect of stimulus type [β=1.16, 95% CI [1.07,1.24], $t(102)=26.70$, $p<0.001$; TOST $t(102)=23.65$, $p=1.000$]. An equally-well fitting model (ΔBIC=0.4) showed the same [β=1.29, 95% CI [1.19,1.39], $t(102)=24.73$, $p<0.001$; TOST $t(102)=21.68$, $p=1.000$], but also showed a significant main effect of gender [β=0.24, 95% CI [0.07,0.42], $t(102)=2.69$, $p=0.008$; TOST $t(102)=-0.36$, $p=0.361$], and a significant interaction effect [β=-0.41, 95% CI [-0.59,-0.23], $t(102)=-4.48$, $p<0.001$; TOST $t(102)=-1.43$, $p=0.922$]. These results indicate that participants rated neutral images more pleasant compared to disgusting images, that men rated the pleasantness of all images as higher than women did, and that women were more likely to show a larger difference between their disgust rating of neutral and disgusting images.

Arousal ratings. The best fitting model (ΔBIC=9.7 for the second-best) for arousal ratings showed an uncorrected statistically significant main effect of stimulus [β=-0.15, 95% CI [-0.30,-0.01], $t(102)=-2.04$, $p=0.044$; TOST $t(102)=1.01$, $p=0.0158$], a significant main effect of moment [β=-0.17, 95% CI [-0.25,-0.09], $t(102)=-4.12$, $p<0.001$; TOST $t(102)=-1.08$, $p=0.859$], and an interaction that was statistically equivalent to no effect [β=-0.03, 95% CI [-0.15,0.08], $t(102)=-0.56$, $p=0.580$; TOST $t(102)=2.49$, $p=0.007$]. These results indicate that participants' arousal ratings reduced along a trial block, and that this reduction was not different between stimulus types.

Supplementary Results – Experiment 2

Eye movement data. Table S2.2 provides the same information as Table 2 in the manuscript. The best-fitting model is described in Table S2.4, and includes gender. In addition to the main manuscript, the most noteworthy points consider the factors trial and gender. While the best-fitting models did not include trial, when it was included (Table S2.1) the interaction effect of stimulus and trial demonstrated that differences between affective and neutral stimuli increased with trial number (this is the opposite of habituation).

When gender was incorporated (Table S2.4), the interaction between gender and stimulus demonstrated a bigger difference in dwell time proportions between affective and non-affective stimuli in women compared to men. There was no main effect of gender (nor a significant equivalence), and the interactions between gender and block, and between gender, stimulus, and block were equivalent to no meaningful effect.

Table S2.1 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (affective vs. neutral), block (disgust vs. fear), and trial (1-24). Model BIC=23777.4*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.43	-0.49	-0.37	-14.92	**<0.001**	-12.06	1.000
Stimulus (reference affective)	0.85	0.80	0.91	30.31	**<0.001**	27.45	1.000
Block (reference disgust)	0.53	0.47	0.58	18.68	**<0.001**	15.82	1.000
Trial	-0.07	-0.11	-0.03	-3.40	**0.001**	-0.54	0.704
stimulus * block	-1.03	-1.11	-0.95	-25.94	**<0.001**	-23.08	1.000
stimulus * trial	0.10	0.05	0.16	3.59	**0.001**	0.73	0.765
block * trial	-0.03	-0.08	0.03	-0.93	0.355	1.93	0.028
stimulus * block * trial	0.01	-0.07	0.09	0.32	0.751	-2.54	**0.006**

Table S2.2 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (affective vs. neutral), block (disgust vs. fear), and trial (1-24). Model BIC=23754.6*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.43	-0.49	-0.37	-14.91	**<0.001**	-12.05	1.000
Stimulus (reference affective)	0.85	0.80	0.91	30.25	**<0.001**	27.39	1.000
Block (reference disgust)	0.53	0.47	0.58	18.64	**<0.001**	15.78	1.000
stimulus * block	-1.03	-1.11	-0.95	-25.89	**<0.001**	-23.03	1.000

Table S2.3 *– Outcomes of a mixed linear model using participant number as random factor. Included factors was stimulus (affective vs. neutral). Model BIC=24371.8*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.17	-0.22	-0.12	-6.63	**<0.001**	-3.77	1.000
Stimulus (reference affective)	0.34	0.30	0.38	16.27	**<0.001**	13.41	1.000

***Table S2.4** – Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (woman vs. man), stimulus (affective vs. neutral), and block (disgust vs. fear). Model BIC=23729.8 (best fit)*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.46	-0.53	-0.40	-14.14	**<0.001**	-11.27	1.000
Gender (reference woman)	0.14	0.01	0.28	2.12	0.037	-0.74	0.230
Stimulus (reference affective)	0.95	0.89	1.01	29.66	**<0.001**	26.80	1.000
Block (reference disgust)	0.53	0.46	0.59	16.49	**<0.001**	13.63	1.000
gender * stimulus	-0.42	-0.55	-0.29	-6.29	**<0.001**	-3.43	1.000
gender * block	-0.01	-0.14	0.12	-0.14	0.889	2.72	**0.004**
stimulus * block	-1.04	-1.12	-0.95	-22.90	**<0.001**	-20.04	1.000
gender * stimulus * block	0.02	-0.17	0.20	0.21	0.836	-2.65	**0.005**

Self-report data. Reported here are linear mixed models for self-reported ratings of disgust, fear, pleasantness, and arousal for all stimuli used in the experiment, across three moments: pre- (before trial 1), mid- (after trial 12), and post-trials (after 24 trials).

The take-home points for these analyses are that disgust ratings are higher for disgusting stimuli compared to all others, and that they reduce by moment. Fear ratings are also different between disgusting stimuli and all others, but do not reduce by moment, with the exception of those for the fear stimulus compared to the disgusting one. Pleasantness ratings are different only for the disgusting stimulus compared to the two neutral stimuli, and showed a reduction that was significant only before Holm-Bonferroni correction. Finally, arousal ratings are significantly different between the disgusting and the neutral stimuli, but not between the disgusting and the fear stimuli (although there is also not a statistically significant equivalence).

Models that included gender systematically underperformed: disgust ΔBIC=55.8, fear ΔBIC=57.5, pleasantness ΔBIC=62.9, and arousal ΔBIC=62.3.

Relevant visualizations and post-hoc tests are reported in the main manuscript (Figure 5).

Table S2.5 *– Outcomes of a mixed linear model of disgust ratings using participant number as random factor. Included factors were stimulus (disgust, neutral control to digust, fear, and neutral control to fear), and moment (pre-, mid-, and post-trials).*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	1.31	1.17	1.44	18.86	**<0.001**	15.87	1.000
Stimulus (neutral disgust) (reference disgust)	-1.85	-2.01	-1.69	-22.27	**<0.001**	-19.28	1.000
Stimulus (fear) (reference disgust)	-1.43	-1.59	-1.26	-17.18	**<0.001**	-14.19	1.000
Stimulus (neutral fear) (reference disgust)	-1.90	-2.06	-1.73	-22.85	**<0.001**	-19.86	1.000
moment	-0.18	-0.27	-0.09	-3.89	**<0.001**	-0.91	0.817
stimulus (neutral disgust) * moment	0.21	0.08	0.34	3.28	**0.001**	0.29	0.615
stimulus (fear) * moment	0.19	0.07	0.32	3.01	**0.003**	0.02	0.508
stimulus (neutral fear) * moment	0.24	0.12	0.37	3.80	**<0.001**	0.82	0.792

Table S2.6 *– Outcomes of a mixed linear model of fear ratings using participant number as random factor. Included factors were stimulus (disgust, neutral control to digust, fear, and neutral control to fear), and moment (pre-, mid-, and post-trials).*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.14	-0.02	0.30	1.66	0.100	-1.32	0.094
Stimulus (neutral disgust) (reference disgust)	-0.54	-0.74	-0.35	-5.61	**<0.001**	-2.62	0.995
Stimulus (fear) (reference disgust)	0.99	0.80	1.18	10.17	**<0.001**	7.18	1.000
Stimulus (neutral fear) (reference disgust)	-0.57	-0.76	-0.38	-5.91	**<0.001**	-2.93	0.998
moment	-0.06	-0.16	0.05	-1.04	0.303	1.95	0.027
stimulus (neutral disgust) * moment	0.09	-0.06	0.23	1.15	0.252	-1.83	0.035
stimulus (fear) * moment	-0.32	-0.46	-0.17	-4.19	**<0.001**	-1.21	0.885
stimulus (neutral fear) * moment	0.04	-0.11	0.19	0.52	0.607	-2.47	0.008

***Table S2.7** – Outcomes of a mixed linear model of pleasantness ratings using participant number as random factor. Included factors were stimulus (disgust, neutral control to digust, fear, and neutral control to fear), and moment (pre-, mid-, and post-trials).*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.79	-0.94	-0.64	-10.30	**<0.001**	-7.31	1.000
Stimulus (neutral disgust) (reference disgust)	1.35	1.15	1.55	13.07	**<0.001**	10.08	1.000
Stimulus (fear) (reference disgust)	0.27	0.06	0.47	2.57	0.012	-0.41	0.341
Stimulus (neutral fear) (reference disgust)	1.38	1.18	1.58	13.35	**<0.001**	10.36	1.000
moment	0.11	0.00	0.23	2.02	0.046	-0.96	0.169
stimulus (neutral disgust) * moment	-0.13	-0.29	0.02	-1.66	0.100	1.33	0.094
stimulus (fear) * moment	-0.01	-0.17	0.15	-0.11	0.911	2.87	**0.002**
stimulus (neutral fear) * moment	-0.15	-0.31	0.00	-1.92	0.057	1.06	0.146

***Table S2.8** – Outcomes of a mixed linear model of arousal ratings using participant number as random factor. Included factors were stimulus (disgust, neutral control to digust, fear, and neutral control to fear), and moment (pre-, mid-, and post-trials).*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.39	0.22	0.56	4.49	**<0.001**	1.50	0.932
Stimulus (neutral disgust) (reference disgust)	-0.55	-0.78	-0.33	-4.81	**<0.001**	-1.82	0.964
Stimulus (fear) (reference disgust)	0.19	-0.04	0.41	1.65	0.101	-1.33	0.093
Stimulus (neutral fear) (reference disgust)	-0.51	-0.73	-0.28	-4.41	**<0.001**	-1.43	0.922
moment	-0.09	-0.21	0.04	-1.37	0.173	1.61	0.055
stimulus (neutral disgust) * moment	-0.05	-0.23	0.12	-0.59	0.554	2.39	0.009
stimulus (fear) * moment	-0.19	-0.36	-0.01	-2.12	0.036	0.86	0.195
stimulus (neutral fear) * moment	-0.12	-0.29	0.06	-1.30	0.196	1.68	0.048

Supplementary Results – Experiment 3

Eye movement data. The best-fitting model is described in Table S3.6, and includes only gender and stimulus, and their interaction. This model shows that dwell time proportions were lower for disgusting compared to neutral stimuli, and that there was a convincing lack of an effect of gender.

In the (worse-fitting) models that did incorporate phase, the only apparent treatment effect was larger disgust avoidance in the post-treatment compared to the pre-treatment, as evidenced by a stimulus by phase interaction (Table S3.1).

Table S3.1 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), phase (pre- vs. post-treatment), and trial (1-10). Model BIC=10587.0*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.23	-0.30	-0.16	-6.36	**<0.001**	-3.42	1.000
Stimulus (reference disgust)	0.47	0.39	0.55	11.03	**<0.001**	8.09	1.000
Phase (reference pre)	-0.11	-0.19	-0.02	-2.49	**0.014**	0.45	0.327
Trial	-0.08	-0.14	-0.02	-2.71	**0.008**	0.23	0.409
stimulus * trial	0.20	0.08	0.32	3.32	**0.001**	0.39	0.650
stimulus * phase	0.13	0.04	0.21	2.95	**0.004**	0.01	0.504
phase * trial	0.02	-0.07	0.10	0.39	0.698	-2.55	**0.006**
stimulus * block * trial	-0.02	-0.14	0.10	-0.32	0.751	2.62	**0.005**

Table S3.2 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), and trial (1-10). Model BIC=10547.3*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.29	-0.34	-0.23	-9.62	**<0.001**	-6.68	1.000
Stimulus (reference disgust)	0.57	0.51	0.63	18.90	**<0.001**	15.96	1.000
Trial	-0.07	-0.12	-0.03	-3.44	**0.001**	-0.50	0.690
stimulus * trial	0.12	0.06	0.18	3.85	**<0.001**	0.91	0.817

Table S3.3 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were stimulus (disgust vs. neutral), and trial (1-10). Model BIC=10547.3*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.29	-0.34	-0.23	-9.61	0.000	-6.67	1.000
Stimulus (reference disgust)	0.57	0.51	0.63	18.87	0.000	15.93	1.000

Table S3.4 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (woman vs man), stimulus (disgust vs. neutral), phase (pre- vs. post-treatment), and trial (1-10). Model BIC=10549.3*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.19	-0.29	-0.09	-3.73	**<0.001**	-0.79	0.785
Gender (reference woman)	-0.11	-0.26	0.03	-1.52	0.131	1.42	0.080
Stimulus (reference disgust)	0.38	0.27	0.50	6.52	**<0.001**	3.58	1.000
Phase (reference pre)	-0.18	-0.29	-0.07	-3.08	**0.003**	-0.14	0.554
Trial	-0.09	-0.18	-0.01	-2.30	0.024	0.64	0.262
gender * stimulus	0.24	0.07	0.40	2.75	0.007	-0.19	0.425
gender * phase	0.16	-0.01	0.33	1.90	0.061	-1.04	0.150
gender * trial	0.02	-0.10	0.14	0.27	0.785	-2.67	0.005
stimulus * phase	0.38	0.22	0.54	4.57	**<0.001**	1.63	0.947
stimulus * trial	0.15	0.04	0.27	2.65	0.010	-0.29	0.385
phase * trial	0.03	-0.08	0.15	0.59	0.559	-2.35	0.010
gender * stimulus * phase	-0.40	-0.63	-0.16	-3.26	**0.002**	-0.32	0.626
gender * stimulus * trial	-0.04	-0.21	0.13	-0.49	0.627	2.45	0.008
gender * phase * trial	-0.02	-0.19	0.15	-0.24	0.810	2.70	0.004
stimulus * phase * trial	-0.03	-0.19	0.13	-0.35	0.730	2.59	0.006
gender * stimulus * phase * trial	-0.01	-0.25	0.22	-0.11	0.916	2.83	**0.003**

Table S3.5 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (woman vs man), stimulus (disgust vs. neutral), and trial (1-10). Model BIC=10475.1*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.28	-0.36	-0.20	-6.78	**<0.001**	-3.84	1.000
Gender (reference woman)	-0.03	-0.15	0.09	-0.52	0.607	2.42	0.009
Stimulus (reference disgust)	0.57	0.49	0.65	13.76	**<0.001**	10.82	1.000
Trial	-0.08	-0.14	-0.02	-2.66	**0.009**	0.28	0.390
gender * stimulus	0.04	-0.08	0.16	0.63	0.532	-2.31	0.011
gender * trial	0.01	-0.08	0.09	0.15	0.885	-2.79	**0.003**
stimulus * trial	0.14	0.06	0.22	3.39	**0.001**	0.45	0.673
gender * stimulus * trial	-0.05	-0.17	0.07	-0.79	0.429	2.14	0.017

Table S3.6 *– Outcomes of a mixed linear model using participant number as random factor. Included factors were gender (woman vs man), and stimulus (disgust vs. neutral). Model BIC=10438.7 (best fit)*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.28	-0.36	-0.20	-6.77	**<0.001**	-3.83	1.000
Gender (reference woman)	-0.03	-0.15	0.09	-0.52	0.607	2.42	**0.009**
Stimulus (reference disgust)	0.57	0.49	0.65	13.74	**<0.001**	10.80	1.000
gender * stimulus	0.04	-0.08	0.16	0.63	0.533	-2.31	**0.011**

Self-report data. Participants provided disgust, pleasantness, and arousal ratings before and after the reward “treatment” phase. Models incorporating gender fit less well compared to those without. The sole exception to this is for arousal, where the best fitting model (ΔBIC=3.7) included gender, stimulus, and their interaction. However, even in that model the main effect of gender was significantly equivalent to no meaningful effect, and there was neither evidence for or against an interaction between gender and stimulus. In sum, stimulus type determined ratings, and gender nor treatment impacted this.

***Table S3.7** – Outcomes of a mixed linear model of **disgust ratings**, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=814.7*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.87	0.73	1.01	12.26	**<0.001**	9.32	1.000
Stimulus (reference disgust)	-1.60	-1.76	-1.43	-18.69	**<0.001**	-15.75	1.000
Phase (reference pre)	-0.31	-0.48	-0.14	-3.61	**<0.001**	-0.67	0.747
stimulus * phase	0.33	0.09	0.57	2.74	**0.007**	-0.19	0.423

***Table S3.8** – Outcomes of a mixed linear model of **disgust ratings**, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=809.5 (best fit)*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.71	0.60	0.83	12.57	**<0.001**	9.63	1.000
Stimulus (reference disgust)	-1.43	-1.55	-1.31	-23.25	**<0.001**	-20.31	1.000

***Table S3.9** – Outcomes of a mixed linear model of **pleasantness ratings**, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=911.4*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.79	-0.94	-0.64	-10.30	**<0.001**	-7.36	1.000
Stimulus (reference disgust)	1.51	1.30	1.73	13.93	**<0.001**	10.99	1.000
Phase (reference pre)	0.28	0.07	0.49	2.57	**0.012**	-0.37	0.356
stimulus * phase	-0.42	-0.72	-0.12	-2.73	**0.008**	0.21	0.416

Table S3.10 *– Outcomes of a mixed linear model of* ***pleasantness ratings****, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=902.5 (best fit)*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	-0.65	-0.76	-0.55	-11.90	**<0.001**	-8.96	1.000
Stimulus (reference disgust)	1.31	1.15	1.46	16.83	**<0.001**	13.89	1.000

Table S3.11 *– Outcomes of a mixed linear model of* ***arousal ratings****, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=1046.7*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.40	0.22	0.59	4.24	**<0.001**	1.30	0.901
Stimulus (reference disgust)	-0.81	-1.04	-0.58	-6.89	**<0.001**	-3.95	1.000
Phase (reference pre)	-0.04	-0.28	0.19	-0.38	0.707	2.56	**0.006**
stimulus * phase	0.11	-0.22	0.43	0.64	0.525	-2.30	**0.012**

Table S3.12 *– Outcomes of a mixed linear model of* ***arousal ratings****, using participant number as random factor. Included factors were gender (man vs. woman) and stimulus (disgust vs. neutral). Model BIC=1026.7 (best fit)*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.35	0.15	0.54	3.43	**<0.001**	0.49	0.689
Gender (reference woman)	0.09	-0.20	0.38	0.64	0.524	-2.30	**0.012**
Stimulus (reference disgust)	-0.61	-0.83	-0.39	-5.39	**<0.001**	-2.45	0.992
gender * stimulus	-0.31	-0.64	0.01	-1.88	0.063	1.06	0.146

Table S3.13 *– Outcomes of a mixed linear model of* **arousal ratings***, using participant number as random factor. Included factors were stimulus (disgust vs. neutral) and phase (pre- vs. post-treatment). Model BIC=1030.4*

Parameter	***β***	***95% CI***		***t***	***p***	***TOST t***	***TOST p***
Intercept	0.38	0.23	0.53	5.11	**<0.001**	2.17	0.984
Stimulus (reference disgust)	-0.76	-0.92	-0.60	-9.13	**<0.001**	-6.19	1.000